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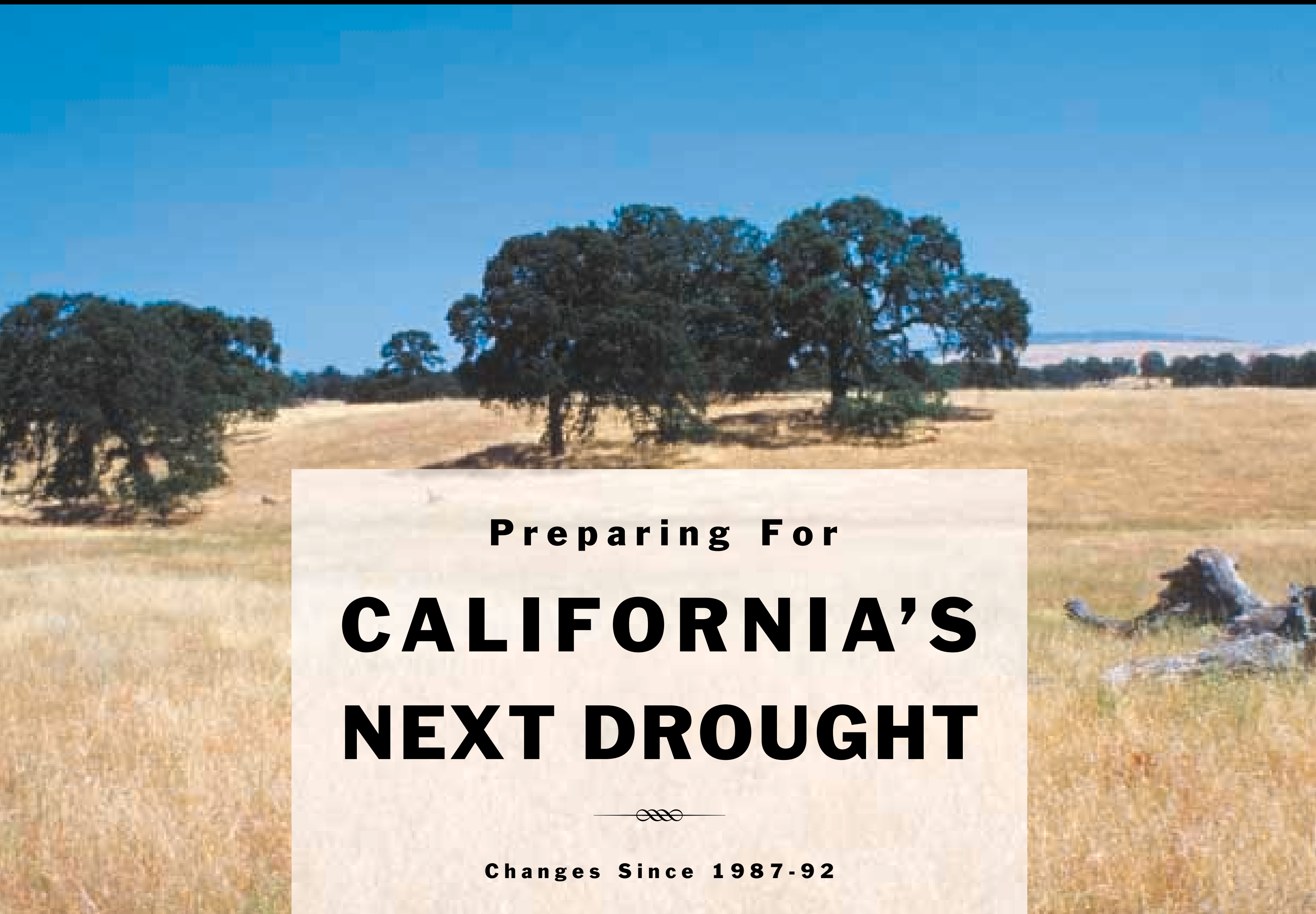

Preparing For

CALIFORNIA'S NEXT DROUGHT

Changes Since 1987-92

— JULY 2000 —

Mary D. Nichols, Secretary for Resources
The Resources Agency

Gray Davis, Governor
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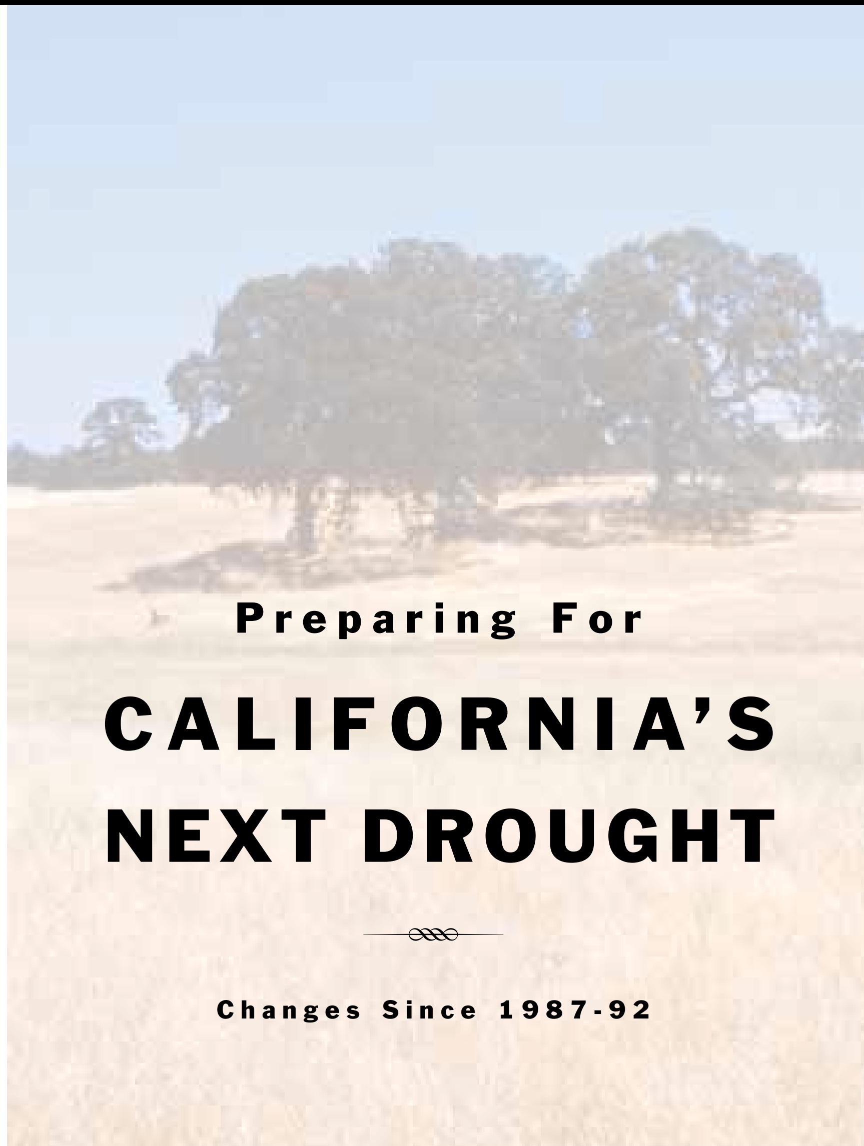

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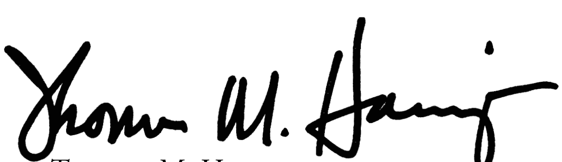
Preparation of this report was initiated in response to the unusually dry conditions experienced through January 2000. California was in the second year of a La Niña event, typically characterized by dryer than normal conditions in the southern part of the State. December 1999 was one of the driest Decembers on record. Snowpack levels in early January in the northern Sierra, the source of much of California's developed water supply, were only some 20 percent of seasonal average. Given that California had previously experienced a record five consecutive wet years, it seemed probable that 2000 would not be another wet year. Subsequently, climatic conditions demonstrated the great variability typical of California. Substantial precipitation and snowpack accumulation brought Northern California to near average water conditions before the end of February.

A dry 2000 would not have constituted a drought for most Californians, especially not with storage in the State's major reservoirs at above average levels as a consequence of the past five wet years. It was recognized, however, that planning should begin for actions to be taken in the event that the following year was also dry. In response to the substantial public interest created by the dry weather conditions, the Department evaluated water supply conditions, changed circumstances since the last drought, and other factors that would affect drought readiness in 2001.

The purpose of this report is to review items that the Department should consider in near-term drought planning, putting California's conditions today into perspective with experiences gained in the 1987-92 drought. The report begins with an overview of California hydrology and water supply, then describes conditions encountered in the 1987-92 drought. Changed conditions since that drought are summarized, and their implications discussed. The report concludes with a list of actions that the Department could take to respond to future drought conditions.

It is essential that California prepare for the return of very dry conditions. On June 9, 2000 Governor Davis and Interior Secretary Babbitt announced a "Framework for Action" as the completion of a five-year planning program to implement specific actions of the CALFED Bay-Delta Program. The Framework included a recommendation that Governor Davis appoint a panel to develop a Drought Contingency Plan by the end of 2000. This report will be used to brief the panel on drought actions considered to date, with the expectation that further and more focused actions/programs may be included in the Governor's Drought Contingency Plan.



THOMAS M. HANNIGAN
Director, Department of Water Resources

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Executive Summary And Key Findings

California rainfall and runoff vary widely throughout the State, and also vary greatly from year to year. The State's historical record of measured runoff amounts to little more than 100 years of data, but other information indicates that California has experienced climatic conditions both wetter and drier than those of the present within the past 1,000 years. Three twentieth century droughts were of particular importance from a water supply standpoint—the droughts of 1929-34, 1976-77, and 1987-92. The purpose of this report is to review conditions experienced by water agencies during the 1987-92 drought, in light of changed water management circumstances, to identify actions the Department could take to prepare for a drought occurring within the next few years.

The 1987-92 drought was notable for its six-year duration and the statewide nature of its impacts. Statewide reservoir storage was about 40 percent of average by the third year of the drought, and did not return to average conditions until 1994. The Central Valley Project and State Water Project met their contractors' delivery requests during the first four years of the drought, but then were forced by declining reservoir storage to reduce deliveries substantially. The SWP terminated deliveries to agricultural contractors and provided only 30 percent of requested urban deliveries in 1991, the single driest year of the drought. A 1991 Governor's executive order created a Drought Action Team to coordinate a response to deteriorating water supply conditions, and directed the Department to implement a drought water bank. Twenty-three counties had declared local drought emergencies by the end of 1991.

California's population has increased by more than 6 million people since the beginning of the last drought. There have been significant changes in California's water management framework. For example, California water users are now preparing a plan and negotiating associated agreements to reduce use of Colorado River water to California's basic apportionment in years when surplus water is not available. Other changes affect the ability of the CVP and SWP to export water from the Sacramento-San Joaquin River Delta. These changes included the new State Water Resources Control Board Bay-Delta water rights decision, Central Valley Project Improvement Act requirements reallocating project water for environmental purposes, Endangered Species Act listing of five new fish species, and management of water operations through the CALFED Operations Group.

New regional water management facilities constructed since the drought include the Department's Coastal Aqueduct, Mojave Water Agency's Mojave River and Morongo Basin Pipelines, Metropolitan Water District's Diamond Valley Lake, and Contra Costa Water District's Los Vaqueros Reservoir. Five new large-scale groundwater recharge/storage projects have gone into operation; several others are in advance planning stages.

Key findings discussed in the report include:

- Defining when a drought occurs is a function of dry conditions' impacts on water users. The Department used two primary criteria to evaluate statewide conditions during the 1987-92 drought—runoff and reservoir storage. A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of the historical range and reservoir storage for the same time period at less than 70 percent of average.
- Drought is a gradual phenomenon. Most natural disasters, such as floods or forest fires, occur relatively rapidly and afford little time for preparing for disaster response. With the exception of impacts to dryland farming and grazing, drought impacts occur slowly over multi-year periods, and increase with the length of dry conditions. Adverse impacts can be reduced by planning appropriate response actions prior to drought onset. The Urban Water Management and Planning Act, for example, requires California's larger urban water suppliers to develop contingency plans for shortages of up to 50 percent.
- Most Californians would experience minimal water supply impacts from a single dry year, thanks to the State's extensive system of water infrastructure. Most of California's major urban and agricultural production areas—with the exception of the Salinas Valley—are within reach of a regional conveyance facility or natural

waterway that would provide access for water transfers or exchanges. The Santa Barbara metropolitan area, the largest urban area to experience major water supply impacts during the 1987-92 drought, is now connected to the State's system of water infrastructure via the State Water Project's Coastal Aqueduct.

- Past droughts demonstrated that water users affected the earliest and to the greatest extent by drought conditions were those not connected to the State's system of water supply infrastructure, but reliant solely on annual rainfall. Typical examples were rural residents supplied by marginal wells, isolated communities relying on springs or small creeks, and ranchers dependent on dryland grazing. Residential water users and small water systems experiencing the most problems were those located in isolated North Coast communities and in the Sierra Nevada foothills. Water haulage and drilling new wells were typical drought response actions in these areas.
- The area at most economic risk from a single dry year would be the west side of the San Joaquin Valley, where dry hydrologic conditions would exacerbate federal water contractors' shortages associated with CVPIA implementation and Delta export restrictions. Significant socioeconomic impacts to low-income Westside farming communities were attributed to the last drought.
- Groundwater extractions increase substantially during droughts. The total number of well construction/modification reports filed with the Department was in the range of 25,000 reports per year during the last drought, up from fewer than 15,000 reports per year prior to the drought. Most new wells were for individual domestic supply. Rural homeowners with private wells are largely an unserved population with respect to drought-related assistance programs, although they constituted many of the public information requests directed to the Department during the last drought. The Department should implement drought outreach programs for these water users.
- Virtually all the State's larger water agencies implemented short-term demand management actions to respond to the last drought. The effects of demand hardening on water agencies' ability to implement shortage contingency measures should be monitored. Statewide, the acreage of permanent agricultural plantings that require water during drought years—such as orchards and vineyards—has increased. Most of the increased acreage is located in the San Joaquin Valley, much of it within the water-short CVP Delta export service area. As urban water agencies implement plumbing fixture retrofit programs or have greater percentages of new housing stock with low water use fixtures, it becomes increasingly difficult for the agencies to implement rationing programs without affecting customers' lifestyles.
- Changed Delta regulatory conditions have rendered the Department's 1993 drought water bank programmatic environmental impact report outdated. A future bank's scope would likely differ from that of the Department's previous banks. Almost 30 percent of California's counties now have local groundwater management ordinances; most ordinances restrict or control groundwater export from a county. Groundwater substitution transfers were a major source of the water purchased by the drought water bank. The proliferation of new county ordinances makes it less likely that the water bank, or local agencies seeking drought water supplies through transfers, would be able to implement transfers involving groundwater.
- Making specific plans for longer-term drought preparedness is complicated by Bay-Delta water management uncertainties. SWRCB's Bay-Delta water rights hearing process remains to be completed. The CALFED program is in a transitional state from planning to implementation, with a decision on its environmental documentation scheduled for later this year. The Bay-Delta Accord will expire in September 2000; discussions are ongoing as to the governance structure that could replace it, including how the function now performed by the CALFED Operations Group might be institutionalized.
- Despite uncertainties associated with Bay-Delta water project operations, having conceptual plans for multi-year operations is an important aspect of drought preparedness. The CALFED Operations Group has been focused on short-term operations under wet hydrologic conditions, responding to day-to-day Delta fishery requirements in the Delta. The last drought demonstrated the need for conservative management of carry-over storage during dry periods. The Department should work

with the CALFED Operations Group or its successor entity, and with the drought panel to be appointed by the Governor as part of CALFED's Bay-Delta Program, to begin conceptual development of multi-year SWP and CVP operations strategies.

- Implementation of many larger agencies' drought response plans is dependent on access to conveyance capacity—in either their own or in other agencies' facilities. The California Aqueduct often figures prominently in such plans, because it is the only facility linking Northern California water supplies with Southern California water users. Availability of aqueduct capacity for wheeling non-project water is becoming increasingly constrained by Delta export restrictions, as well as by contractual commitments and increasing SWP contractors' water demands. The growing number of south-of-Delta groundwater recharge/storage programs further contributes to wheeling requests. Considering the increasing level of interest in aqueduct wheeling, it may now be time for the Department to adopt a formal priority system for access to aqueduct capacity.

Hydrology And Water Supply

This chapter briefly summarizes California hydrology and water supplies and describes hydrologic conditions associated with past droughts. It is important to remember that California hydrologic data cover a limited period of historical record—only a few stream gages have a period of record in excess of 100 years, and likewise only a few precipitation records extend as much as 150 years. Efforts to go beyond the historical period of record to evaluate the occurrence of earlier droughts, or to forecast future droughts, are described at the end of this chapter.

The water supplies used by Californians come from several sources—surface water released from reservoirs, surface water directly diverted from unstored streamflows, and groundwater. Supplies derived from desalting and water recycling are also important to individual agencies relying on these sources, but they collectively represent less than one percent on California's water supply.

Roughly three-quarters of California's runoff occurs north of Sacramento, while about the same proportion of water needs occurs south of Sacramento. Figure 1 shows the extensive system of conveyance infrastructure constructed in response to the imbalance in the locations of supplies and demands. Access to this conveyance capacity has important implications for water transfers, as discussed in Chapter 3.

SURFACE WATER HYDROLOGY AND SUPPLY

Much of California enjoys a Mediterranean-like climate with cool, wet winters and warm, dry summers. An atmospheric high pressure belt results in fair weather for much of the year, with little precipitation during the summer. The high pressure belt shifts southward during the winter, placing the State under the influence of Pacific storms bringing rain and snow. Most of California's moisture originates in the Pacific Ocean. As moisture-laden air moves over mountain barriers such as the Sierra Nevada, the air is lifted and cooled, dropping rain or snow on the western slopes. This orographic precipitation is important for the State's water supply.

Average annual statewide precipitation is about 23 inches, corresponding to a volume of nearly 200 million acre-feet over California's land surface. About 65 percent of this precipitation is consumed through evaporation and transpiration by plants. The remaining 35 percent comprises the State's average annual runoff of about 71 maf. Less than half this runoff is depleted by urban or agricultural use. Most of it maintains ecosystems in California's rivers, estuaries, and wetlands. Available surface water supply totals 78 maf when interstate supplies from the Colorado and Klamath Rivers are added. Figure 2 shows the distribution of California's average annual precipitation and runoff.

On average, 75 percent of the State's average annual precipitation of 23 inches falls between November and March, with half of it occurring between December and February. A shortfall of a few major storms during the winter usually results in a dry year; conversely, a few extra storms or an extended stormy period usually produces a wet year. An unusually persistent Pacific high pressure zone over California during December through February predisposes the year toward a dry year. Figure 3 compares average monthly precipitation in the Sacramento River region with precipitation during extremely wet (1982-83) and dry (1923-24) years.

THE WATER YEAR

Water agencies such as the Department or the U.S. Geological Survey report hydrologic data on a water year basis. The water year extends from October 1st through September 30th. This report, for example, was published in water year 2000 (October 1, 1999—September 30, 2000). Hydrologic data presented throughout this report are presented in terms of water years. The (water year) 1987-92 drought corresponds to the calendar period of fall 1986 through summer 1992. Water project delivery data (*e.g.,* State Water Project deliveries) are presented on a calendar year basis.

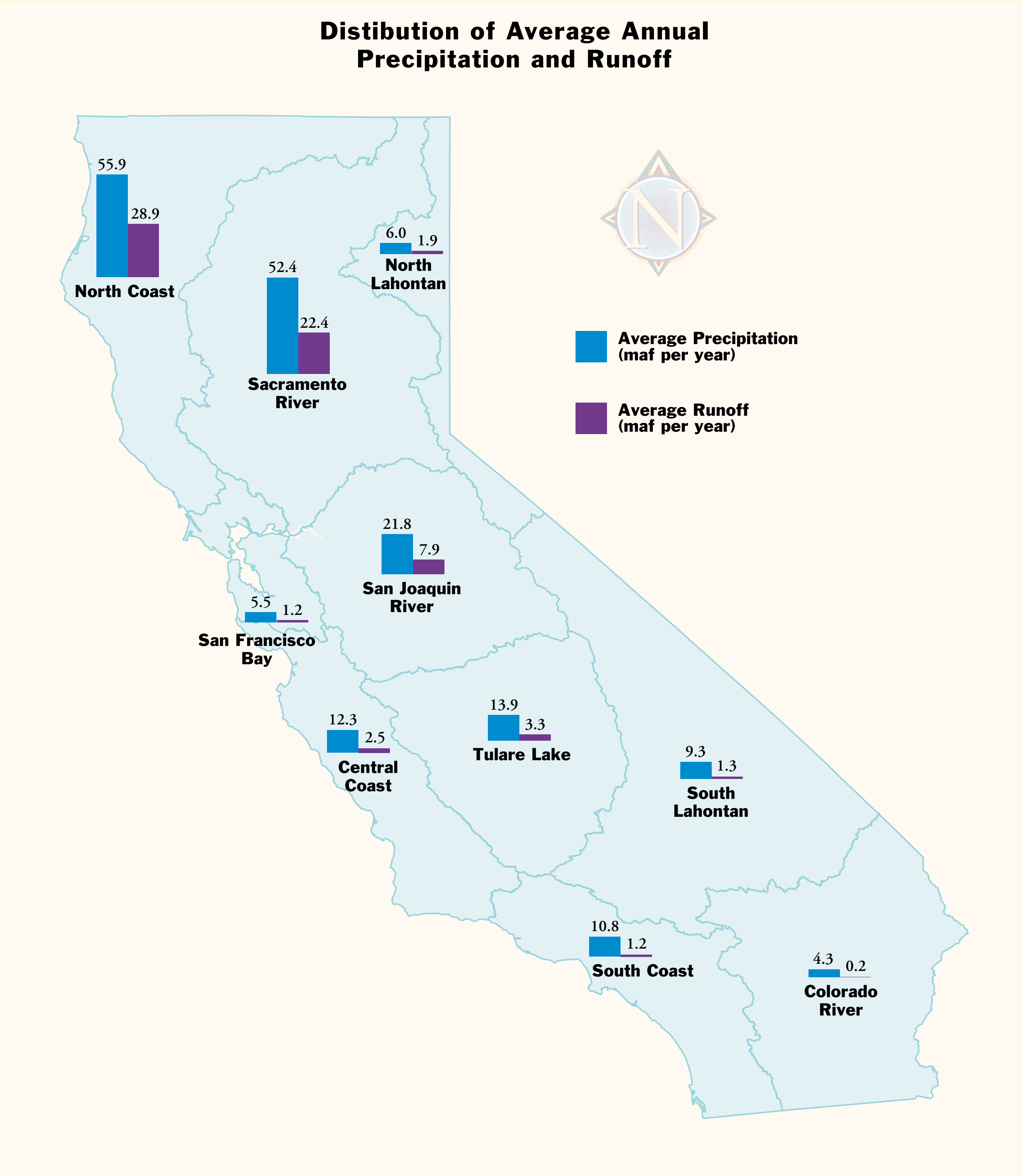
—FIGURE 1—

California's Major Water Projects

The influence of climatic variability on California's water supplies is much less predictable than are the influences of geographic and seasonal variability, as evidenced by the recent historical record of precipitation and runoff. For example, the State's average annual runoff of 71 maf includes the all-time low of 15 maf in 1977 and the all-time high (exceeding 135 maf) in 1983. Floods and droughts occur often, sometimes in the same year. The January 1997 flood was followed by a record-setting dry period from February through June; the flooding of 1986 was followed by six years of drought (1987-92).

Figures 4 and 5 show estimated annual unimpaired runoff from the Sacramento and San Joaquin River

—FIGURE 2—



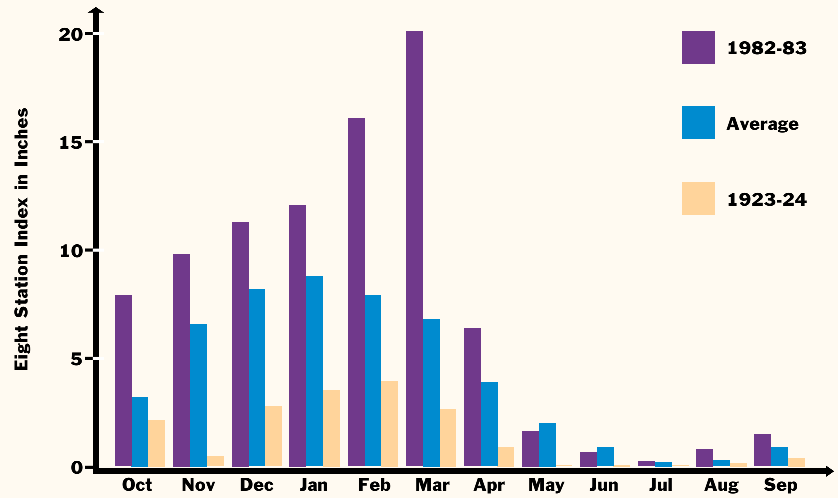
Basins to illustrate climatic variability. Because these basins provide much of the State's water supply, their hydrologies are often used as indices for water year classification systems.

Water year classification systems provide a means to assess the amount of water originating in a basin. The Sacramento Valley 40-30-30 Index and the San Joaquin Valley 60-20-20 Index were developed by the State Water Resources Control Board for the Sacramento and San Joaquin River Basins as part of SWRCB's Bay-Delta regulatory activities. Both systems define one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types.

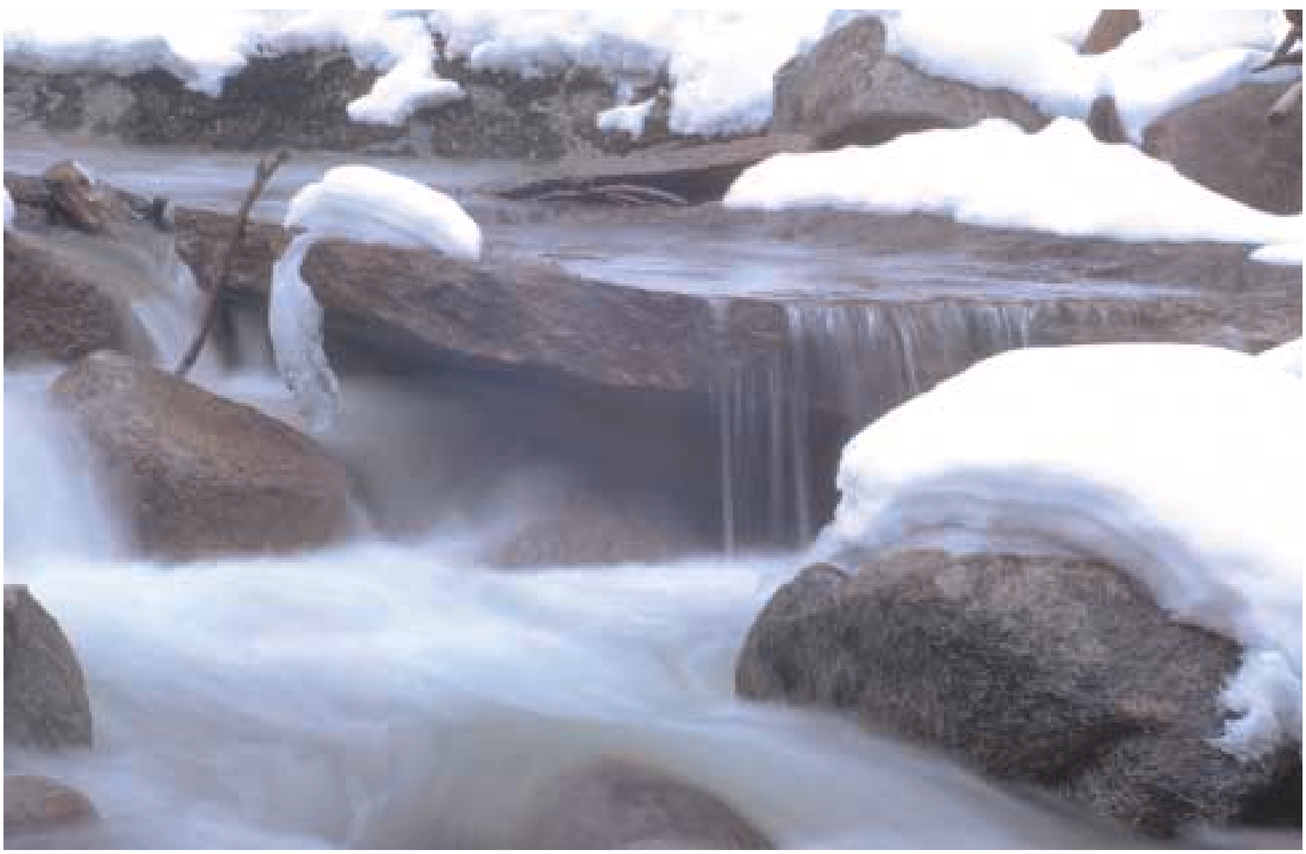
The Sacramento Valley 40-30-30 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (40 percent), the current water year's October-March unimpaired runoff (30 percent), and the previous water year's index (30 percent). A cap of 10 maf is put on the previous year's index to account for required flood control reservoir releases during wet years. Unimpaired runoff (calculated in the 40-30-30 Index as the sum of Sacramento River unimpaired flow above Bend Bridge, Feather River unimpaired inflow to Oroville Reservoir, Yuba River unimpaired flow at Smartville, and

—FIGURE 3—

Northern Sierra Eight Station Precipitation Index



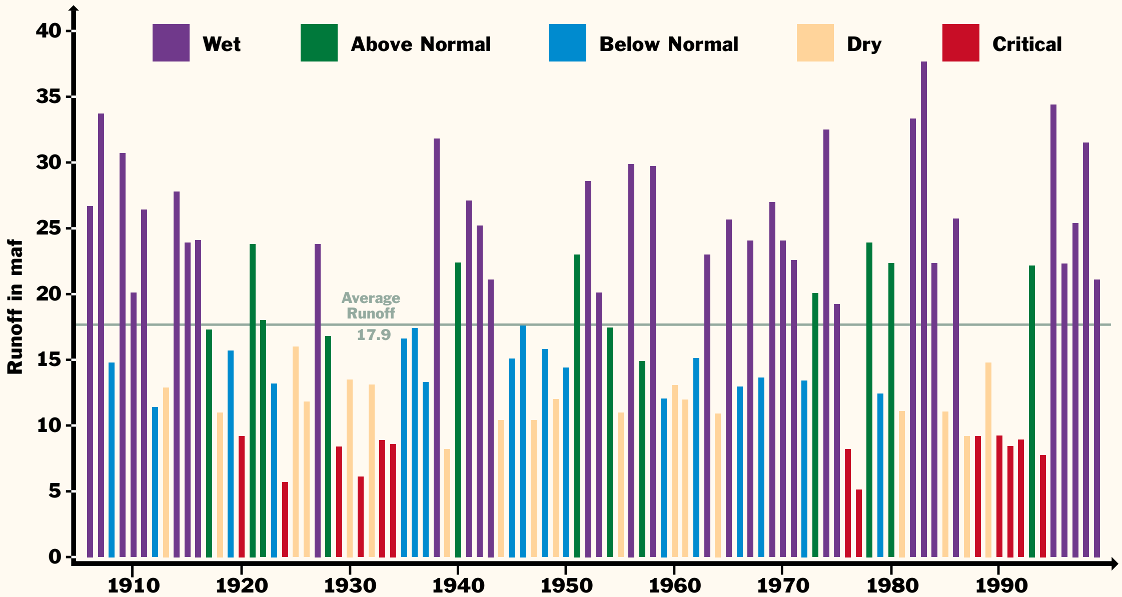
The eight stations are:
Mt. Shasta City; Shasta Dam; Brush Creek; Mineral; Quincy; Sierraville; Blue Canyon; Pacific House



Snowmelt runoff in the Sierra Nevada provides much of California's developed water supply. Every year, snowpack depth and water content are measured at selected sites throughout the Sierra as part of a cooperative snow surveys program. This information is used to forecast spring runoff, allowing reservoir operators to plan for the coming year.

—Figure 4—

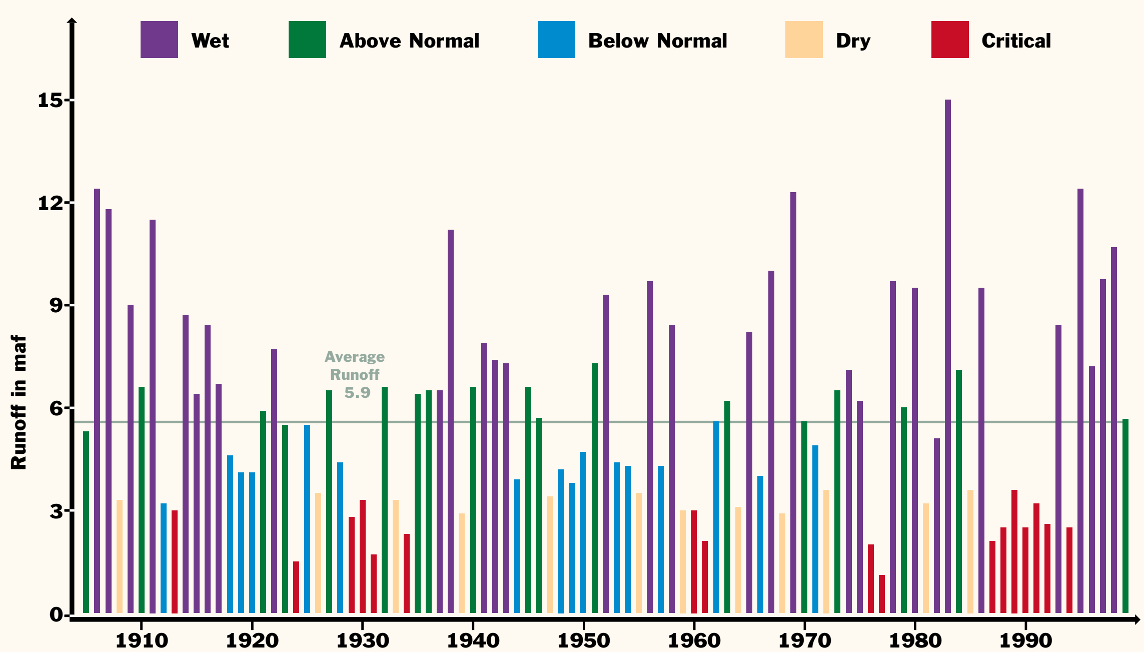
Sacramento Four Rivers Unimpaired Runoff



The Sacramento Four Rivers are: *Sacramento River above Bend Bridge, near Red Bluff; Feather River inflow to Oroville; Yuba River at Smartville; American River inflow to Folsom*

—Figure 5—

San Joaquin Four Rivers Unimpaired Runoff



The San Joaquin Four Rivers are: *Stanislaus River inflow to New Melones, Tuolumne River inflow to New Don Pedro, Merced River inflow to New Exchequer, San Joaquin River inflow to Millerton*

American River unimpaired inflow to Folsom Reservoir) is river production unaltered by water diversions, storage, exports, or imports. A water year with a 40-30-30 index equal to or greater than 9.2 maf is classified as "wet." A water year with an index equal to or less than 5.4 maf is classified as "critical." Unimpaired runoff from the Sacramento Valley, often referred to as the Sacramento River Index or the Four River Index, was the dominant water supply index used in SWRCB's Decision 1485. The SRI, while still used in SWRCB's Order WR 95-6 as a water supply index, is no longer employed to classify water years. By considering water availability from storage as well as from seasonal runoff, the 40-30-30 Index provides a more representative characterization of water year types than does the SRI. However, no indexing scheme can be a perfect representation of water year type. For example, the inability to store large volumes of wet year runoff (due to reservoir flood control requirements and the relatively low ratio of storage capacity to wet year runoff volumes for most California rivers) distorts the 40-30-30 Index value for the year following a very wet year.

The San Joaquin Valley 60-20-20 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (60 percent), the current water year's October-March unimpaired runoff (20 percent), and the previous water year's index (20 percent). A cap of 4.5 maf is placed on the previous year's index to account for required flood control reservoir releases during wet years. San Joaquin Valley unimpaired runoff is defined as the sum of unimpaired inflow to New Melones Reservoir (from the Stanislaus River), Don Pedro Reservoir (from the Tuolumne River), New Exchequer Reservoir (from the Merced River), and Millerton Lake (from the San Joaquin River). A water year with a 60-20-20 index equal to or greater than 3.8 maf is classified as "wet." A water year with an index equal to or less than 2.1 maf is classified as "critical."

Although not used to classify water years, the Eight River Index is another water supply index employed in Order WR 95-6. The Eight River Index, defined as the sum of the unimpaired runoff from the four Sacramento Valley Index rivers and the four San Joaquin Valley Index rivers, is used to define Delta outflow requirements and export restrictions. Key index months for triggering Delta requirements are December, January, and February.

GROUNDWATER SUPPLY

Under average hydrologic conditions, about 30 percent of California's urban and agricultural water needs are supplied by groundwater. This percentage increases in dry years when water users whose surface supplies are reduced turn to groundwater, if available.

—Figure 6—

Total Well Driller Reports Filed Annually with DWR

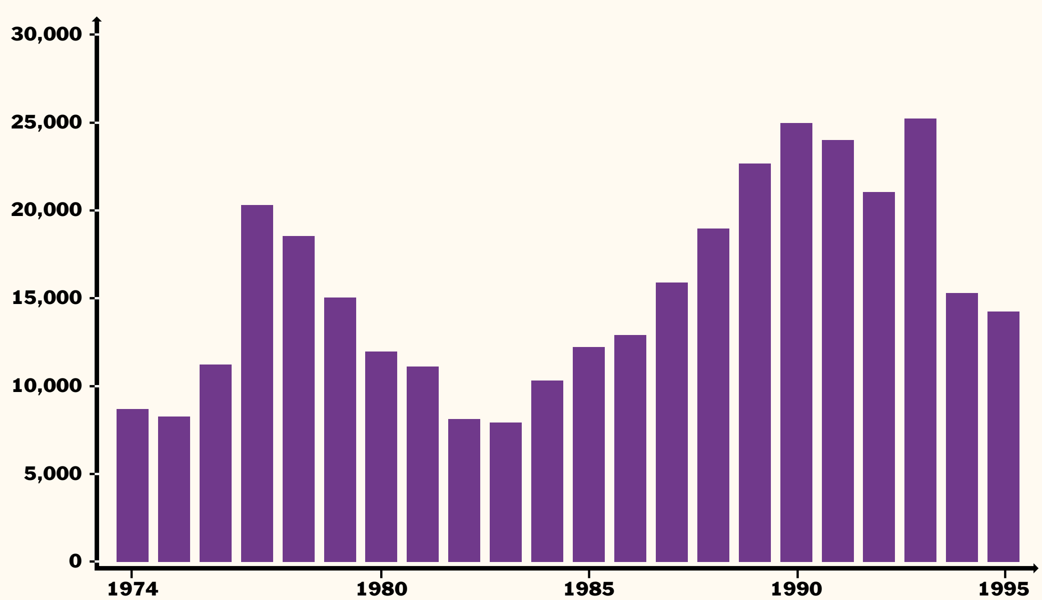
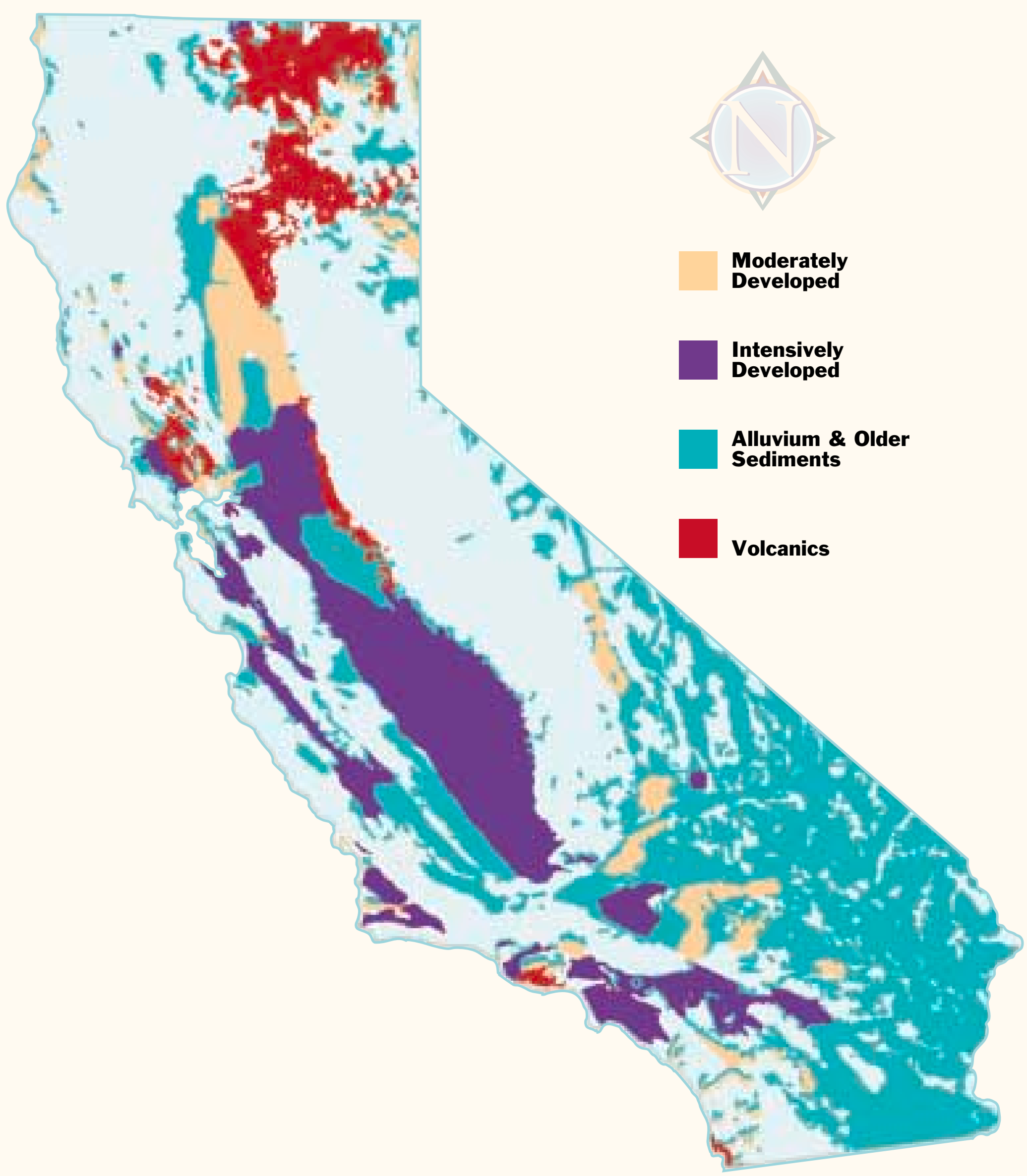


Figure 6 shows the total number of well construction/modification reports received annually by the Department, illustrating the relationship between groundwater use and hydrologic conditions. Well drilling activity increased during the 1987-92 drought and was at a minimum in wet years such as 1982 or 1983.

The amount of water stored in California's groundwater basins is far greater than that stored in the State's surface water reservoirs, although only a fraction of these groundwater resources can be economically and practically extracted for use. Figure 7 shows major areas of current and potential groundwater development in California. The greatest amounts of groundwater extraction occur in the Central and Salinas Valleys and in the Southern California coastal plain. At a 1995 level of development, California's estimated developed groundwater supplies were about 12.5 maf under average hydrologic conditions. This amount is exclusive of groundwater overdraft, estimated at about 1.5 maf annually. More than 1 maf of this estimated annual overdraft occurs in the San Joaquin Valley.

—FIGURE 7—

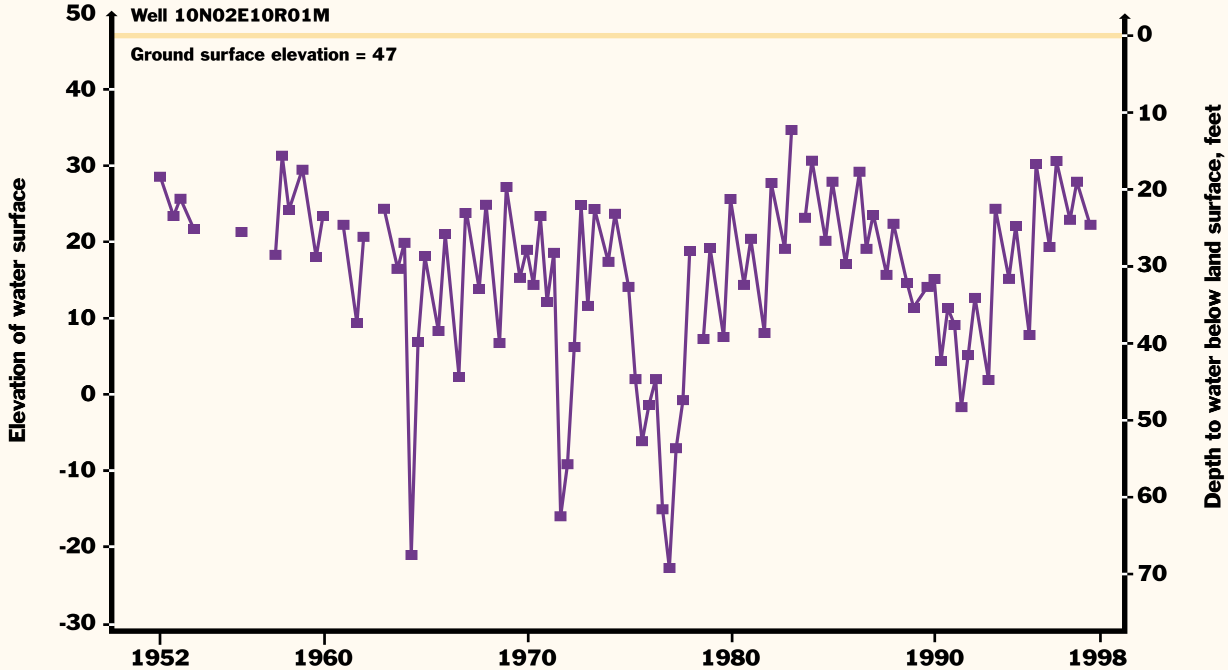
Areas of Current and Potential Groundwater Development



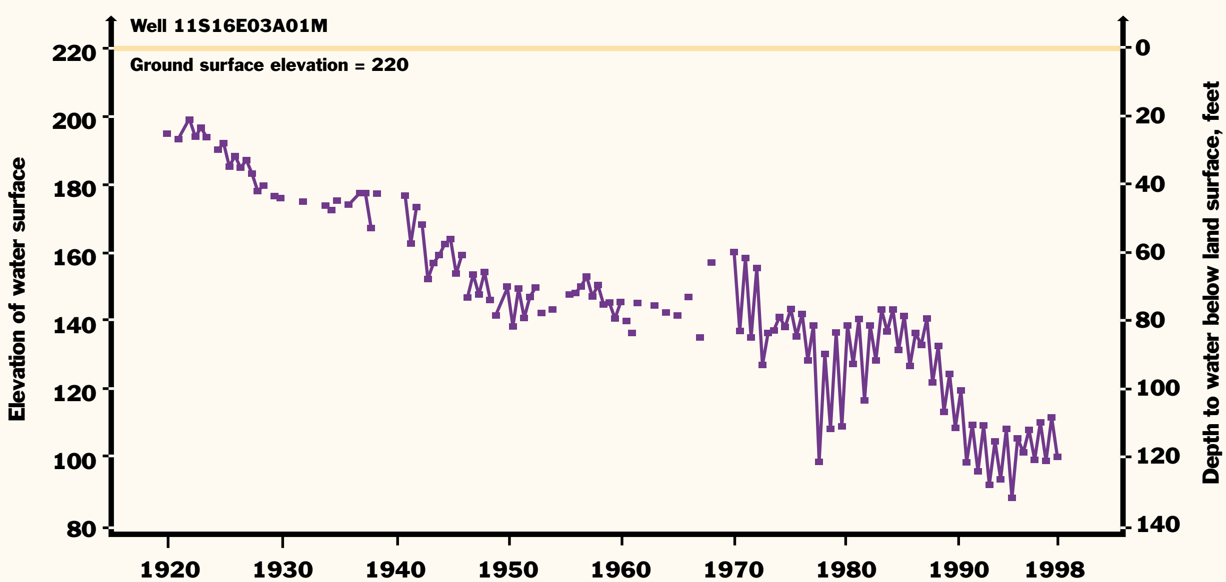
—FIGURE 8—

Sample Hydrographs of Agricultural Wells in the Sacramento and San Joaquin Valleys

Sacramento Valley, Yolo County



San Joaquin Valley, Madera Basin



The majority of California's groundwater production occurs from alluvial materials in the large basins indicated in Figure 7. Groundwater levels in such basins typically decline during droughts due to increased extractions. For example, groundwater extractions were estimated to exceed recharge by 11 maf in the San Joaquin Valley during the first five years of the 1987-92 drought. Drawing down groundwater reserves in drought years is analogous to surface reservoir carryover storage operations. The extent to which groundwater levels recover depends on the amount of subsequent extractions and recharge. Figure 8 shows hyrographs for two wells—one located in a basin experiencing long-term overdraft and the other in a basin not experiencing long-term overdraft. Both hydrographs show the effects of increased extractions during the 1976-77 and 1987-92 droughts, followed by post-drought rebound.

PAST CALIFORNIA DROUGHTS

Droughts exceeding three years are relatively rare in Northern California, the source of much of the State's water supply. Historical multi-year droughts include: 1912-13, 1918-20, 1923-24, 1929-34, 1947-50, 1959-61, 1976-77, and 1987-92. The 1929-34 drought established the criteria commonly used in designing storage capacity and yield of large Northern California reservoirs. Table 1 compares the 1976-77 and 1987-92 droughts to the 1929-34 drought in the Sacramento and San Joaquin Valleys.

One approach to supplementing California's limited period of measured data is to statistically reconstruct data through the study of tree rings. Information on the thickness of annual growth rings can be used to infer the wetness of the season. A 420-year reconstruction of Sacramento River runoff from tree ring data was made for the Department in 1986 by the Laboratory for Tree Ring Research at the University of Arizona. The tree ring data suggested that the 1929-34 drought was the most severe in the 420-year reconstructed record from 1560 to 1980. The data also suggested that a few droughts prior to 1900 exceeded three years, and none lasted over six years, except for one period of less than average runoff from 1839-46. John Bidwell, an early pioneer who arrived in California in 1841, confirmed that 1841, 1843, and 1844 were extremely dry years in the Sacramento area. The Department is currently funding the University to expand tree ring data for the Sacramento River watershed to cover approximately the past 1,000 years. Similar tree ring studies covering the period between 1550 and 1977 were conducted for the Colorado and Santa Ynez Rivers. According to these studies, the most severe drought on the Colorado River occurred during 1580-1600, and the most severe drought on the Santa Ynez River occurred during 1621-37.

A 1994 study of relict tree stumps rooted in present-day lakes, rivers, and marshes suggested that California sustained two epic drought periods, extending over more than three centuries. The first epic drought lasted more than two centuries before the year 1112; the second drought lasted more than 140 years before 1350. In this study, the researcher used drowned tree stumps rooted in Mono Lake, Tenaya Lake, West Walker River, and Osgood Swamp in the central Sierra. A conclusion that can be drawn from these investigations is that California is subject to droughts more severe and more prolonged than anything witnessed in the historical record.

—TABLE 1—

Severity of Extreme Droughts in the Sacramento and San Joaquin Valleys

Drought	Sacramento Valley Runoff		San Joaquin Valley Runoff	
Period	(maf/yr)	(% Average 1901-96)	(maf/yr)	(% Average 1906-96)
1929-34	9.8	55	3.3	57
1976-77	6.6	37	1.5	26
1987-92	10.0	56	2.8	47

PAST CALIFORNIA DROUGHTS

The historical record of California hydrology is brief in comparison to the time period of geologically modern climatic conditions. The following sampling of changes in climatic and hydrologic conditions help put California's twentieth century droughts into perspective, by illustrating the variability of possible conditions. Most of the dates shown below are necessarily approximations, since the dates must be inferred from indirect sources.

11,000 years before present	Beginning of Holocene Epoch—Recent time, the time since the end of the last major glacial epoch
6,000 years before present	Approximate time when trees were growing in areas now submerged by Lake Tahoe. Lake levels were lower then, suggesting a drier climate.
900—1300 A.D. *(approximate)*	The Medieval Warm Period, a time of warmer global average temperatures. The Arctic ice pack receded, allowing Norse settlement of Greenland and Iceland. The Anasazi civilization in the Southwest flourished, its irrigation systems supported by monsoonal rains.
1300—1800 A.D. *(approximate)*	The Little Ice Age, a time of colder average temperatures. Norse colonies in Greenland failed near the start of the time period, as conditions became too cold to support agriculture and livestock grazing. The Anasazi culture began to decline about 1300 and had vanished by 1600, attributed in part to drought conditions that made agriculture infeasible.
Mid-1500s A.D.	Severe, sustained drought throughout much of the continental U.S., according to dendrochronolgy. Drought suggested as a contributing factor in the failure of European colonies at Parris Island, South Carolina and Roanoke Island, North Carolina.
1850s A.D.	Sporadic measurements of California precipitation began.
1890s A.D.	Long-term streamflow measurements began at a few California locations.

PREDICTING FUTURE DROUGHTS

Accurate long-term weather forecasting would be extremely valuable for water project operations. Currently, predictions sufficiently detailed to be useful for project operations are limited to about two weeks at best, and these predictions have perhaps a 50 percent accuracy rate. Had water project operators known in advance that 1987-92 would be dry, project operations could have been modified to increase carry-over storage and to equalize deliveries over the six years of drought.

Long-term forecasting remains in its scientific infancy. The National Weather Service issues 30 and 90-day forecasts. Academic institutions, such as the Scripps Institution of Oceanography in San Diego, have attempted experimental seasonal forecasts. The accuracy and level of detail of these efforts remains insufficient for water project operations. It is only recently, for example, that researchers have had sufficient understanding of global weather patterns and atmospheric/oceanic interactions to be able to identify conditions associated with the El Niño Southern Oscillation in the Pacific Ocean. That understanding has yet to be translated to forecasts of runoff, partly because ENSO events affect different parts of California differently.

Using global weather models to predict future climatological conditions requires collection of massive amounts of data and access to substantial computational power (*i.e.,* supercomputers). Although electronic data processing capabilities have increased exponentially since the early days of mainframe computers, data collection will remain a limiting factor into the foreseeable future, due to the sheer volume of information needed to represent global atmospheric/oceanic conditions. Atmospheric conditions themselves may furthermore be inherently too variable to support long-range forecasts of sufficient reliability for short-term water project operations. A more realistic expectation might be the ability to forecast shifts in global conditions, such as potential global warming or decadal oscillations in ocean temperatures in the equatorial Pacific. It can be safely said that the ability to accurately predict dry conditions will remain elusive within this report's short planning horizon.

Excavations for construction of Metropolitan Water District's Diamond Valley Lake in Riverside County yielded numerous paleontologic resources, including partial remains of mastodons. The mastodons, together with other extinct species such as long-horned bison and ground sloths, occupied Diamond and Domenigoni Valleys during the Pleistocene Epoch, the time of the last Ice Age. The area's climate was then cooler and wetter than the present. Photograph courtesy of MWD.

DROUGHTS—WHEN WATER USERS LACK WATER

One dry year does not constitute a drought in California, but does serve as a reminder of the need to plan for droughts. California's extensive system of water supply infrastructure—its reservoirs, groundwater basins, and inter-regional conveyance facilities—mitigates the effect of short-term dry periods. Defining when a drought begins is a function of drought impacts to water users. Hydrologic conditions constituting a drought for water users in one location may not constitute a drought for water users in a different part of the state or with a different water supply. Individual water suppliers may use criteria such as rainfall/ runoff, amount of water in storage, or expected supply from a water wholesaler to define their water supply conditions

Figure 9 illustrates several indicators commonly used to evaluate California water conditions. The percent of average values are determined for measurement sites and reservoirs in each of the State's ten major hydrologic regions. Snowpack is an important indicator of runoff from Sierra Nevada watersheds, the source of much of California's developed water supply.

The Department used two primary criteria to evaluate statewide drought conditions during the 1987-92 drought—runoff and reservoir storage, either actual or predicted. A drought threshold was considered to be runoff for a single year or multiple years in the lowest ten percent of the historical range, and reservoir storage during the same time period at less than 70 percent of average. These were not hard and fast values, but guidelines for identifying drought conditions.

Drought is a gradual phenomenon. Although droughts are sometimes characterized as emergencies, they differ from typical emergency events. Most natural disasters, such as floods or forest fires, occur relatively rapidly and afford little time for preparing for disaster response. Droughts occur slowly, over a multiyear period. There is no universal definition of when a drought begins or ends. Impacts of drought are typically felt first by those most reliant on annual rainfall—ranchers engaged in dryland grazing, rural residents relying on wells in low-yield rock formations, or small water systems lacking a reliable water source. Criteria used to identify statewide drought conditions do not address these localized impacts. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

—FIGURE 9—